DOI: https://doi.org/10.30932/1992-3252-2020-18-6-272-303



# Central Andean Railway in Peru

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**ABSTRACT**

*Built in the late 19th century, the Central Andean Railway in Peru was created through attracting foreign capital and foreign engineering ideas. Large-scale plans for exploitation of the richest deposits of copper, silver and gold formed the basis for construction of this railway line. The engineering solutions used in this project impress specialists even today. In particular, the so-called zigzags, which made it possible to lay a route along the inaccessible mountain ranges of the Andes. As the main investor of the project, American entrepreneur Henry Meiggs, once once said that the train will arrive there where llama can get.*

*The chief engineer, author of the project, overseeing construction of the Central Railway, was Ernest Malinowski, a Polish specialist, honorary citizen of Peru.*

*«The project of engineer Ernest Malinowski provides for construction of a railway line at an altitude of almost 5000 meters above sea level, which is impossible. The implementation of the bridges and viaducts designed by him seems to be risky», – this is how his contemporaries evaluated the project of the Polish engineer.*

*Keywords:* *railway, mountain railway, history of railways, zig zag/reverse, railway bridges, railway tunnel, rolling stock, heavy axle load, Central Andean railway.*

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Article received 02.11.2020, accepted 21.12.2020.

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**Technical parameters**

The Peruvian Ferrocarril Central Andino (FCCA) starts off the Pacific coast and ends in the area of copper mines high in the Andes. The train begins its journey in Callao within the metropolitan area of Lima, that is, from the port to La Oroya station, where the railway is divided into two directions, one of which leads north to Cerro de Pasco station, and the other south to Huancayo station. The length of the railway is 490 km, including Callao–Huancayo section of 346 km. The most impressive facts about the Central Railway are the height of its location above sea level, which reaches a maximum value of 4782 m (Galera station on the 173$^{d}$ km of the route), as well as the presence of 69 tunnels with a total length of 10,8 km, 58 bridges with a length of 1,8 km and also of six double changes of direction of movement (the famous zig zag or switchback track), which were built in order to ensure the maximum allowable gradient of the track of 29–37 ‰ per 100 km, between the stations of San Bartolomé at km 76 situated 1513 m above sea level (masl) and Ticlio at km 171, 4758 masl, where the train overcomes the difference in altitude of 3245 m (Table 1). The maximum gradient is 96,5 ‰ between Tambo and Jauja stations (this is an isolated case, and there is no reverse movement in this section).

The Central Andean Railway is a single-track, non-electrified line. The track width is 1435 mm. The author of the project is Polish engineer Ernest Malinowski, the main investor is Henry Meiggs, a businessman from the United States. The track in the sections with the greatest gradient is laid on rocky ledges. Numerous bridges and tunnels of the famous road are structures, the size of which does not exceed 200 m (most of them are 50 to 100 m long). There are many switchback sections, and the most spectacular moment is a change in direction of movement in Balta Tunnel. In most cases, the switches are manually transferred by train crew. Difficult topographic conditions are the reason for the average speed on tracks to not exceed 40 km/h. It should be added that until completion of construction of the Trans-Tibetan Railway in China in 2007, the Central Andean Railway of Peru remained the «highest» railway in the world[1, 2].

The construction of the railway in the Andes was associated with plans to exploit the rich deposits of copper ore in Peru, as well as the accompanying silver and gold ores deposits (currently Peru and Chile are the main exporters of these metals in the world). Copper is still in great demand. More than 60 % of copper is used for production of electrical wires. Among metals, only silver has a higher conductivity.

Compared to other South American railway networks, the Central Andean Railway differs (in addition to its height) by a standard gauge

[1] Currently Tanggula station (5072 m above sea level) on Trans-Tibet railway (Qinghai–Tibet railway / Qingzang railway) is the highest railway station in the world.
[2] Another high railway line in South America is Atofagasta line in Chile, with its highest point at 4818 meters above sea level, and it is also used to transport copper ore.


***Chosica railway station (54$^{th}$ km, 860 m above sea level) (21.03.2010). Photo: N. Öberg.***

**Table 1**

**Technical parameters of Callao—Lima—Huancayo section of the Central Andean Railway**

| Station | km | Height, m asl | Gradient, ‰ | Remarks |
|---|---|---|---|---|
| Patio y factoria Guadalupe | 1 | 3,0 | 0,6 | |
| Patio central / Callao | 2 | 3,6 | 13,3 | |
| Monserrate | 13 | 150,0 | 0,0 | |
| Desamparados | 14 | 150,0 | 16,9 | |
| Vitarte | 26 | 353,0 | 16,7 | |
| Santa Clara | 29 | 403,0 | 18,3 | |
| Chosica | 54 | 860,0 | 29,7 | |
| Tornamesa | 74 | | | Zig zag |
| San Bartolomé | 76 | 1513,0 | 33,7 | |
| Matucana | 102 | 2390,0 | 34,3 | |
| Viso | 111 | | | Zig zag bottom/Zig zag top |
| Tamboraque | 120 | 3008,0 | 35,6 | |
| Cacray | | | | Zig zag |
| Cacray | | | | Direction of travel is reversed |
| Rio Blanco | 134 | 3506,0 | 32,6 | |
| Chicla | 141 | 3733,9 | 35,0 | Direction of travel is reversed |
| Saltacuna | | | | Direction of travel is reversed |
| Casapalca | 153 | 4154,0 | 29,4 | |
| Backus | | | | Direction of travel is reversed |
| Johnston | | | | Direction of travel is reversed |
| Chinchan | 160 | 4360,0 | 36,2 | |
| Ticlio | 171 | 4758,0 | 11,5 | Branch in the direction of Morococha, 14 km (4538,0 m asl) |
| Galera | 173 | 4781,0 | 29,5 | |
| Rumichaca | | | | Zig zag (south) / zig zag (north) |
| Yauli | 193 | 4192,0 | 33,4 | |
| Arapa | 198 | 4025,0 | 0,0 | |
| Mahr Tunel | 196 | 4025,0 | 7,1 | |
| Cut-Off | 206 | 3954,0 | 14,3 | |
| La Oroya | 222 | 3726,0 | 4,9 | |
| Pachacayo | 262 | 3529,0 | 4,9 | |
| Llocllapampa | 275 | 3465,0 | 4,4 | |
| Tambo | 299 | 3359,0 | 96,5 | |
| Jauja | 301 | 3552,0 | 14,4 | |
| Matahuasi | 321 | 3265,0 | 4,3 | |
| Concepcion | 324 | 3252,0 | 1,2 | |
| San Jeronimo | 330 | 3245,0 | 1,0 | |
| Huancayo | 346 | 3261,0 | | |

[4; 17]. In other Latin American countries (Chile, Argentina, Brazil), track gauges of 1000 mm, 1600 mm or 1676 mm are common, while the standard track gauge of 1435 mm is extremely rare.

The highest point of the railway is located in La Cima at 4835 m above sea level on Ticlio—Morococha section near the local mine. The tracks run along the Rimac River and its tributaries past Chinchan station, located seven kilometers from Casapalca station (at the 153$^{d}$ km, 4154 meters above sea level) in the western Andes. This station served as a transfer station for the mined ore.

Further, the railway leads through Galera tunnel, the longest and the highest (4781 m above sea level) tunnel of the railway. Then the average height above sea level decreases, gradients become less steep. At Yauli station (at the 193$^{d}$ km, 4192 masl) the railway runs along the river with the same name. Then the railway «meets» the Mantaro River, which it crosses and reaches Tambo station (at the 299th km, 3359 masl). Then it crosses beautiful localities such as Jauja (301st km, 3552 masl), Matahuasi (321st km, 3265 masl), Concepcion (324th km, 3252 masl) and at the very end of the track leads to Huancayo (346th km, 3261 masl).

Today, a highway has already been laid both in La Oroya and Huancayo. For highways, steeper gradients and smaller radii of curves are allowed, as well as there are other technologies developed in the second half of 20th century. However, railway transport is traditionally chosen for transportation of heavy goods.

The Peruvian Central Andean Railway is currently operated by Ferrocarril Central Andino (FCCA), which is owned by private entrepreneur Juan Olaechea and RDC group, who received a 30-year concession after the Central Railway had been privatised in mid-1999. Other shareholders of FCCA are Ferrovías e Infraestructura (Olaechea group), Minas Buenaventura, ADR Inversiones UNACEM (leading cement manufacturer in Peru) [6; 8]. Copper ore and pure copper are transported by 36 locomotives and 881 wagons [15]. It should be emphasised that almost all railways in Peru were built to transport goods, not passengers, and that many of them currently remain closed for operation. The main modes of transport in Peru are buses and air transport[3].

**History of the Central Andean Railway**

The Central Andean Railway was designed and built by Ernest Malinowski, whose family voluntarily left their country for political reasons. E. Malinowski studied at École nationale des Ponts et Chaussées in Paris, which he graduated with an engineering degree [5]. Upon arriving in Peru in 1851 the Polish engineer was tasked with developing a project to extend Lima–Callao railway along Jauja valley towards the Andes mountain range. The Peruvian government created a technical commission composed of Felipe Barreda, Mariano Felipe Paz Soldán and Manuel Pardo, which was tasked with collecting information on local topography, geological and climatic conditions. The information was necessary for development of a preliminary project, which was entrusted to E. Malinowski. Peru's Parliament (Congress) passed the railway laws proposed by the Government and guaranteed payment of six percent rate on the construction investment. A commission was also created to study four possible (alternative) routes, which would also start in Lima and lead through:

1) Rimac River Gorge and the localities of Matucana, San Mateo and Tarma.

2) Gorge of the Chillón River, and the localities of Caballero, Yangas, Obrajillo, Casachanca and Carhuacancha.

3) The Chancay River Gorge and the localities of Chancay, Macas, Huatamantaga, Huaillay and Cerro de Pasco.

4) The gorge of the Lurin River and the localities of Sisicaya, Tupicocha, San Damian, Tuctucocha, Pumacocha, Oroya, Tarma and Jauja.

According to the prepared report, construction across the Rimac River Gorge was difficult, but possible. The construction of a railway through the gorges of the Chillón and Chancay rivers was assessed as almost impossible, while construction across the gorge of the Lurin river was considered very simple. The choice was made in favour of the fourth option, the detailed study of which and development of the project were entrusted to the engineer Gerrit Backus. He was considered one of the best specialists in the field of railway construction. Backus prepared a project, but in March 1866 work was suspended due to the war with Spain. Two years later, government member Don Diego Masias contacted Henry Meiggs, a US businessman based in Chile (he worked there under a contract). The American in September 1868 presented to the government of Peru the idea of building Lima–Jauja railway. Eyewitnesses then said that he convinced the central authorities of Peru with the argument *«I will build the railway track where the llamas run»*. A work plan and construction budget of 27 million pesos were approved. H. Meiggs' proposal was accepted and the mandatory completion date was determined within six years in exchange for government bonds with six percent per annum and 2% amortised bonds, with a ten-year implementation period. The contract was concluded between the government of Peru and Mr. H. Meiggs in December 1869 in the form of a public act. The first article there-of read:

[3] The large area of Peru (1,29 million sq. km.), the terrain (mountain ranges of the Andes, with the highest peak Huascaran 6768 m above sea level), and the equatorial climate (heavy rainfall) in the eastern part of the country make maintenance of land infrastructure (highways) laborious and costly. Therefore, in the case of long-distance travel in Peru, air transport is preferable.

«Henry Meiggs, his heirs, executors or legal representatives undertake to build a section of the Central Andean Railway (Spanish: Ferrocarril Central Transandino), between Callao and Lima-La Oroya; according to the plan and technical drawings developed by the chief engineer Ernest Malinowski with participation of the engineer Pedro Marzo, appointed by the government, which were approved and deposited with the government office» [18].

The work began on January 1, 1870 with a loud event, during which the first stone was laid at the site of what is now Monserrate station in Lima, under the direction of the head of the technical corps, engineer Ernest Malinowski. In order to facilitate construction, the main line Lima–La Oroya (222 km) was divided into sections:

1. Lima–Callao–Cocachacra.
2. Cocachacra–San Bartolomé–San Jerónimo de Surco.
3. San Jerónimo de Surco–Matucana.
4. Matukana–Parac (San José de Parac).
5. Parac–San Mateo–Rio Blanco.
6. Rio Blanco–Galera.
7. Galera–La Oroya.

However, life made its own adjustments – Mr. Meiggs managed to build a railway only to the city of Chicla (3733,9 masl), 141 kilometers from Callao. Meiggs faced serious difficulties in paying salaries to hired engineers, workers and managers. The government has suspended construction of the railway. Only selected sections were completed:

- Cocachacra – in February 1871;
- San Bartolomé – in September 1871;
- Chicla – in May 1878.

Henry Meiggs died in 1879. As a result of a conflict between investors and the Government of Peru, construction was paralysed until 1890, when the bondholders assumed the rights and responsibilities of Meiggs and organised the Peruvian Corporation, which became the legal successor. On July 12, 1892, the railway reached Casapalca and in January 1893 – La Oroya. These were the last stations of the Central Railway.

The construction of the section between La Oroya and Huancayo began in 1905, but the next agreement between the government and the Peruvian Corporation was concluded only in 1907 (during this period of time, part of the work was carried out by the state), so the work was completed in September 1908. In total, construction of the Central Andean Railway took 38 years.

The most outstanding engineering structures of this railway are Verrugas or Carrión viaducts 175 m long and 80 m high and Galera tunnel with a length of 1177 m. Also noteworthy is Balta spiral tunnel (at the 94th km) long of 1375 m. This tunnel is overcome by a train in 4–5 minutes. The most impressive sections and stations of the Central Andean Railway are:

- zig zag section Carcay–Rio Blanco station;
- section Casapalca–Chinchán–Ticlio–Galera;
- section near station Chicla;
- section near station San Bartolomé;
- section near Balta tunnel;
- station La Oroya.

The Central Andean Railway begins its journey at the railway station in Lima at Desamparados Station, which is in the centre of the capital of Peru, a building designed by the architect Rafael Marquin in 1912.

**Peruvian Corporation**

Based on the loan, which the Peruvian state took to finance the construction, in accordance with article 26 of the agreement of March 20, 1890, a company was created, which accepted to manage the 160 km of the constructed railway line.

Due to the enormous debts cumulated by the Peruvian government during construction of the Central Railway, The Peruvian Corporation Ltd was formed under the Joint Stock Companies Act on March 20, 1890. The company was created in order to pay off external debt and repay government loans that were taken out by bondholders to finance construction of the Peru Central Railway. The main purpose of the corporation was to transfer rights and obligations of bondholders.

Two weeks later, the company's shares were listed on London Stock Exchange. This deal was completed, the heirs of H. Meiggs (his sons J. G. Meiggs, H. G. Meiggs, and also Alejandro R. Robertson) sold to the Peruvian Corporation their shares in the Central Railway and their shares in Cerro de Pasco silver mines.

In 1891, the Peruvian Corporation decided to take over the management of all the railways of the country and turn them into subsidiaries, dividing the shares among themselves. Seven companies emerged, five of which were controlled by subsidiaries. The two others were established through third parties, because there were still valid contracts with the state and other private individuals.

Predictably, given the economic crisis the country faced after the war with Chile, there were problems with fulfillment of the contract. In 1893, payment interruptions began and Parliament tried to suspend annual payments to creditors. The Peruvian Corporation was unable to secure funding for construction of the following sections. Until 1899, the parties did not come to any agreements and the next round of negotiations began only in 1904, and in June 1907 a new contract was signed stating that:

1) The Peruvian Corporation will finance construction of all new planned railways with a total length of about 300 km.

2) The railway company will reimburse the state for all costs incurred in partial construction of these roads.

3) The right to operate the railway by the company will be extended for another 17 years, provided that the state treasury begins to pay 80 thousand British pounds, which will be obtained from the sugar tax.

The Peruvian corporation operated the Central Andean Railway continuously until 1927, and temporarily until March 1973.

**National railway company: ENAFER**

After the coup d'état and the rule of the military junta in 1968–1975 it was decided to nationalise many enterprises that were managed by foreign companies. The French firm Sofresrail was asked to conduct an analysis of the payback of private domestic railway carriers and a study on profitability of the country's railways, after that in April 1971 a decision was made to nationalise them. This also affected roads belonging to the Peruvian Corporation, headquartered in Canada. The official pretext for this referred to insufficient investment in the company. On December 1, 1972, the National Railroad Company, better known as ENAFER Peru, was created, which united all the railways of the country, except for La Oroya-Cerro di Pasco section, since it was very profitable and belonged to a North American company. Since January 1973, ENAFER Peru has operated lines:

- Callao–Lima–La Oroya–Huancayo;
- Huancayo–Huancavelica;
- Mollendo–Arequipa–Puno;
- Juliaca–Cusco–Matarani–La Joya;
- Cusco–Quillabamba.
- Arica–Tacna.

In July 1973, a bank loan was obtained for purchase of rolling stock and infrastructure elements:

- spare parts for rolling stock in operation in the amount of 12,6 mln US dollars;
- 300 freight wagons and 32 passenger cars in Romania;
- 12,7 thousand tons of rails in Canada.
- 25 diesel locomotives, 36 wagons for transporting ore from mines and 40 tank cars from Japan.

ENAFER Peru was restructured in 1976 and Congress approved loans for modernisation in 1979. At this time, Peru's railway network was of 1691 km. From the 1980s to the early 1990s, the volume of transportation decreased due to intensive operation of lines and insufficient funding for their maintenance. A real problem was also the activities of political extremists from the Sendero Luminoso group, who operated mainly in the mountainous regions of Peru. For this reason, in 1991 a decision was made to re-privatise the company. A year earlier, termination of passenger transportation was announced. But cargo transportation was also systematically reduced, and railway operation brought only losses every year. In 1998, the last repairs were carried out for 12 locomotives and 100 cars, as well as for 41 km of tracks, and in mid-July 1999 the company was closed. The shares were transferred to new owners. The carrier FVCA (Ferrovías Central Andina SA) is operated by Juana de Dios Olaechea, a private individual who has been granted a concession to operate the transport for the next 30 years. FVCA's shareholders are Mitsui, Buenaventura, RDC, Inversiones Andina and CDC. ENAFER retained the operation of Arica–Tacna section.

FVCA originally operated the following railways:

1) Main railway Callao–La Oroya, 222 km.

2) Railway La Oroya–Huancayo, 124 km.

3) Lima–Ancon line, 37,3 km, was finally abandoned and dismantled in 1965. It was part of the old northwestern railway, which included Lima–Ancon–Chancay line, which started operation in December 1870. During the war with Chile, Ancon–Chancay section was destroyed by the Chileans and was never rebuilt.

Table 2

**Locomotives and rolling stock motor units, used by Peruvian Railways**

| Manufacturer | Series | Years of production | Axle scheme | Weight of rolling stock unit, t | Max. speed, km/h | Power of diesel engine, kW | Power of diesel engine, kW | Number of units | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| GM-EMD | GR12 | 1953–1968 | Bo'Bo' | 72 | 100 | 1310 | 977 | 2 | Modified driver's cabs |
| MLW | DL532B | 1961–1962 | Bo'Bo' | ND | ND | 1035 | 772 | 3 | Shunting locomotives, only 1 locomotive in operable state. The second is waiting for repairs |
| MLW | ALCO-DL560 | 1962–1998 | Co'Co' | 113 | 120 | 2600 | 1940 | 1 | Purchased as new ones from the manufacturer |
| EMD | GM C22CW | 1969–1974 | Co'Co' | 92 | 120 | 1500 | 1119 | 2 | 1 unit removed from operation |
| EMD | SD40-2<br>SD-40 | 1972–1989 | Co'Co' | 167 | 105 | 3000 | 2238 | 2<br>1 | One locomotive SD-40 has a modified diesel engine cooling system |
| GE | C30 7PA | 1976–1985 | Co'Co' | 191 | 113 | 3000 | 2238 | 4 | Modified due to oversizing when passing through Matukana and Galera tunnels |
| GE | C30M-3 | 1976–1985 | Co'Co' | 191 | 113 | 3000 | 2238 | 2 | Modernised at the plant Locomotoras San Luis in Mexico |
| GE | C30M-3<br>C36-7p<br>C39-08 | 1976–1985<br>1978–1989<br>1984–1987 | Co'Co' | 191<br>191<br>ND | 113<br>113<br>113 | 3000<br>3600<br>3900 | 2238<br>2686<br>2909 | 3<br>1<br>1 | Locomotives purchased after 2000, and removed from operation |
| GE | B39-E8 | 1983–1994 | Bo'Bo' | ND | ND | 3900 | 2909 | 2 | |
| GE | C39-08 | 1984–1987 | Co'Co' | ND | 113 | 3900 | 2909 | 8 | |
| GE | C39-8P | 1984–1987 | Co'Co' | ND | 113 | 3900 | 2909 | 8 | Purchased from Conrail from the USA, modified due to oversizing when passing through Matukana and Galera tunnels |
| EMD | JT26CW-2B | 1985–1995 | Co'Co' | 126 | 120 | 3000 | 2238 | 3 | Commissioned in June 2020 |
| GE | C-40CW | 1989–1994 | Co'Co' | ND | 113 | 4000 | 2984 | 2 | Obtained from the carrier CSX from USA in May 2020 |
| EMD | GT42AC | 1999–2005 | Co'Co' | 120 | 100 | 3300 | 2460 | ND | |
| Beyer–Peacock | ND | ND | 1'D | ND | ND | ND | ND | 1 | British-made steam locomotive; decommissioned |
| DUEWAG AG | ND | ND | ND | ND | ND | ND | ND | 3 | Motor cars from the future tram line in Lima–Chosica |

* Values obtained from converting mile/h to km/h (e.g., value of 113 km/h corresponds to 70 mile/h).
Bo'Bo' means a loco with two bogies each of them having two separately powered axles. Co'Co' means three driving wheels sets.

4) The railway to Ticlio-Morococha mining branch, 14,3 km, operated under a concession granted in 1899 and has been in operation since 1903.

5) The railway to Morococha mining branch, 18,6 km, was built in 1921 as a branch of La Oroya–Huancayo line (at the 205th km) near Pachachaca. This route has reduced the distance of transporting ore from Morococha to the La Oroya metallurgical plant by several kilometers, significantly reducing costs.

6) Final destination Espinar–Cusco.

**Rolling stock**

The first steam locomotives on the Peruvian railway network appeared in 1870. They came from the United States and were produced by Rogers and Danforth, and after 1890 also by Baldwin and Alco. In 1908, steam locomotives of NBL type, made in Great Britain, were in operation. Most of all locomotives are «heavily» used rolling stock units, purchased in most cases from US railway companies.

A distinctive feature of the South American railways has always been the use of a large axle load – 30–35 tons, due to which a large traction force is provided. This makes it possible, when using double traction and an automatic coupling of AAR type, to form very heavy trains, which is important for freight traffic. Diesel locomotives[4] currently used by Peruvian carriers are mostly manufactured by companies in the United States and Canada: General Electric, Electro-Motive Diesel of General Motors (respectively GE and GM EMD) and Montreal Locomotive Works (MLW). The power of diesel engines of locomotives operating on hauls ranges from 2000 to 3000 kw, which, together with the aforementioned high axle load and Co'Co' axle system (for example, 32 t for the C30M-3 series), is absolutely sufficient for two locomotives to haul a heavy freight train. Locomotives, like most rolling stock in the Americas, have only one driver's cab. Locomotives and motor rolling stock units used on Peruvian railways are listed in Table 2 (the list may be unexhaustive).

**La Oroya – railway hub and metallurgical centre**

The place where copper ore is processed is La Oroya, a city in the centre of Peru, founded in 1533 by the Spaniards, who began to mine non-ferrous metals on a large scale in the area. However, export problems slowed down production growth. During the Peruvian War of Independence, the strategic location of the city made it a centre of guerrilla activity and the site of one of decisive battles of the Chacamarca (Junin) war. The present name has existed since 1893, and in 1942 the area of La Oroya was endowed with the rights of an urban settlement (since 1925 it is the capital of the province of Yauli). Large-scale mining of copper ore began in 1893 with completion of the railway from Lima.

In 1922, a metallurgical plant was built, the investor was the American corporation Cerro de Pasco, which operated the enterprise until 1974, i.e. before nationalisation by the state. Then the plant was incorporated into the company Empresa Minera del Centro del Peru SA, also known as Centromin [11]. However, already in 1993, it was decided to privatise the metallurgical plant by Doe Run Peru, a subsidiary of the Renco Group, for 247 mln US dollars. The buyer spent 120,5 mln US dollars on purchase of the plant and 126,5 mln US dollars on investment in the plant. Plus, the new owner bought the Cobriza copper mine for 7,5 mln US dollars to supply the plant with copper ore. The metallurgical plant in La Oroya is the main employer for local residents. Along with the metallurgical plant, the city also has factories that process lead ore (since 1928) and zinc ore (since 1952), producing 70 thousand tons of copper, 122 thousand tons of lead and 45 thousand tons of zinc. However, the location of the factories is at a considerable height of 3726 masl and under the conditions of rarefied air (less oxygen, lower pressure), and this imposed several constraints regarding production process. Copper ore in La Oroya is mined with a large amount of harmful impurities that cannot be removed during the flotation process. However, technologists have succeeded in developing new methods for separating and recovering metals in the form of by-products. For this purpose, local

[4] Electric traction in South and North America is used to a limited extent, primarily by suburban railways or the surface metro system around major cities such as Montreal, Buenos Aires or São Paulo, using direct current from an overhead contact network (e.g. 1.5 kV DC) or catenary rail (600–750 V DC). The exception is the NEC mainline in the USA, a line used for express trains and Amtrak's Acela Express, powered by 3 types of AC.

smelteries were forced to actively integrate with each other. La Oroya is one of the few locations in the world that have that capability. As a result, gold and silver, antimony, arsenic trioxide, bismuth, cadmium, indium, selenium, tellurium, sulfuric acid and oleum are produced here. This helps to reduce emissions of harmful and toxic metals. But these three metallurgical plants went to the new owners «badly shabby». The previous owner did not attach importance to modernisation. As a result, the work of these plants currently violates many environmental standards, which leads to an excess of MPC (maximum permissible concentration) in the air of arsenic by 85 times, cadmium by 41 times and lead by 13 times[5]. High concentrations of lead have been found both in the blood of local residents and in drinking water. As a result, the inhabitants of La Oroya quite often suffer from chronic diseases of the respiratory system [16].

**Copper ore: mining, processing and economic significance**

Man has been using copper for more than ten thousand years and it plays a special role in development of civilisation (for example, the Bronze Age is associated with an alloy of copper and lead). 95 % of copper that is currently in use was mined after 1900. The Latin name for copper, *cuprum*, comes from Cyprus, where it was originally mined. Along with production of electrical wires, this metal is also used for roofing and manufacture of drainpipes (20 %), and industrial machines (15 %). It is worth emphasising that 35 % of copper from 22,1 million tons (2009) of the total world production is obtained in the recycling process [14].

It is easy to see that about half of all copper mined in the world was obtained in Peru and Chile – about nine million tons (Table 3). The development of copper deposits pays off if its content in the ore is 0,5 %, it is very profitable to start mining ore with a copper content of more than 2 %. Despite the fact that copper still often appears in nuggets, it is most often found in the form of sulfides and oxides:

• cuprite $Cu_2O$ (89 %);

[5] The listed chemical elements cause chronic poisoning and have a carcinogenic effect. Arsenic and its compounds, for example, white arsenic, are especially toxic.

Table 3

**Copper production [2]**

| Place in the ranking | Country/ Region | 2017 | 2018 | reserves |
|---|---|---|---|---|
| | | mln tons | | |
| | World | 20,00 | 20,67 | 830 |
| 1 | Chile | 5,50 | 5,80 | 170 |
| 2 | Peru | 2,45 | 2,40 | 83 |
| 3 | China | 1,71 | 1,60 | 26 |
| 4 | USA | 1,26 | 1,20 | 48 |
| 5 | DRC | 1,09 | 1,20 | 20 |
| 6 | Australia | 0,86 | 0,95 | 88 |
| 7 | Zambia | 0,79 | 0,87 | 19 |
| 8 | Mexico | 0,74 | 0,76 | 50 |
| 9 | Russia | 0,71 | 0,71 | 61 |
| 10 | Indonesia | 0,62 | 0,78 | 51 |
| 11 | Other countries | 4,25 | 4,40 | 210 |

Table 4

**Share of metals in export of Peru (2018) [13]**

| Total export value | bln US dollars | % |
|---|---|---|
| | 53,5 | 100,00 |
| Copper ores | 11,2 | 20,93 |
| Gold | 6,86 | 12,82 |
| Refined copper, copper alloy and copper wires | 2,16 | 4,04 |
| Zinc ores | 0,81 | 1,51 |
| Lead ores | 0,85 | 1,59 |
| Crude zinc | 1,984 | 3,71 |
| Iron ores | 0,744 | 1,39 |
| Non-ferrous metals, raw materials | 0,697 | 1,30 |
| Molybdenum ores | 0,631 | 1,18 |
| Raw tin | 0,256 | 0,48 |
| Silver | 0,355 | 0,66 |
| Total | 26,55 | 49,62 |

Table 5

**Silver production [2]**

| Place in the ranking | Country/ Region | 2017 | 2018 | reserves |
|---|---|---|---|---|
| | | thousand tons | | |
| | World | 26,8 | 27 | 560 |
| 1 | Mexico | 6,11 | 6,1 | 37 |
| 2 | Peru | 4,30 | 4,3 | 110 |
| 3 | China | 3,50 | 3,6 | 41 |
| 4 | Poland | 1,29 | 1,3 | 110 |
| 5 | Chile | 1,26 | 1,3 | 26 |
| 6 | Bolivia | 1,24 | 1,2 | 22 |
| 7 | Australia | 1,20 | 1,2 | 89 |
| 8 | Russia | 1,12 | 1,2 | 45 |
| 9 | USA | 1,03 | 0,9 | 25 |
| 10 | Argentina | 1,02 | 1,1 | bd. |
| 11 | Other countries | 4,77 | 4,8 | 57 |

Table 6

**Gold production [2]**

| Place in the ranking | Country/ Region | 2017 | 2018 | reserves |
|---|---|---|---|---|
| | | tons | | |
| | World | 3181 | 3261 | 54 100 |
| 1 | China | 426 | 400 | 2 000 |
| 2 | Australia | 301 | 310 | 9 800 |
| 3 | Russia | 270 | 295 | 5 300 |
| 4 | USA | 237 | 210 | 3 000 |
| 5 | Canada | 164 | 185 | 2 000 |
| 6 | Peru | 151 | 145 | 2 600 |
| 7 | RSA | 137 | 120 | 6 000 |
| 8 | Ghana | 128 | 130 | 1 000 |
| 9 | Mexico | 126 | 125 | 1 400 |
| 10 | Uzbekistan | 104 | 105 | 1 800 |
| 11 | Other countries | 1137 | 1236 | 19 200 |

- chalcocite $Cu_2S$ (80 %);
- bornite $Cu_5FeS_4$ (63 %);
- malachite $Cu_2CO_3(OH)_2$ (57 %);
- azurite $Cu_3(CO_3)_2(OH)_2$ (53 %);
- chalcopyrite $CuFeS_2$ (35 %),

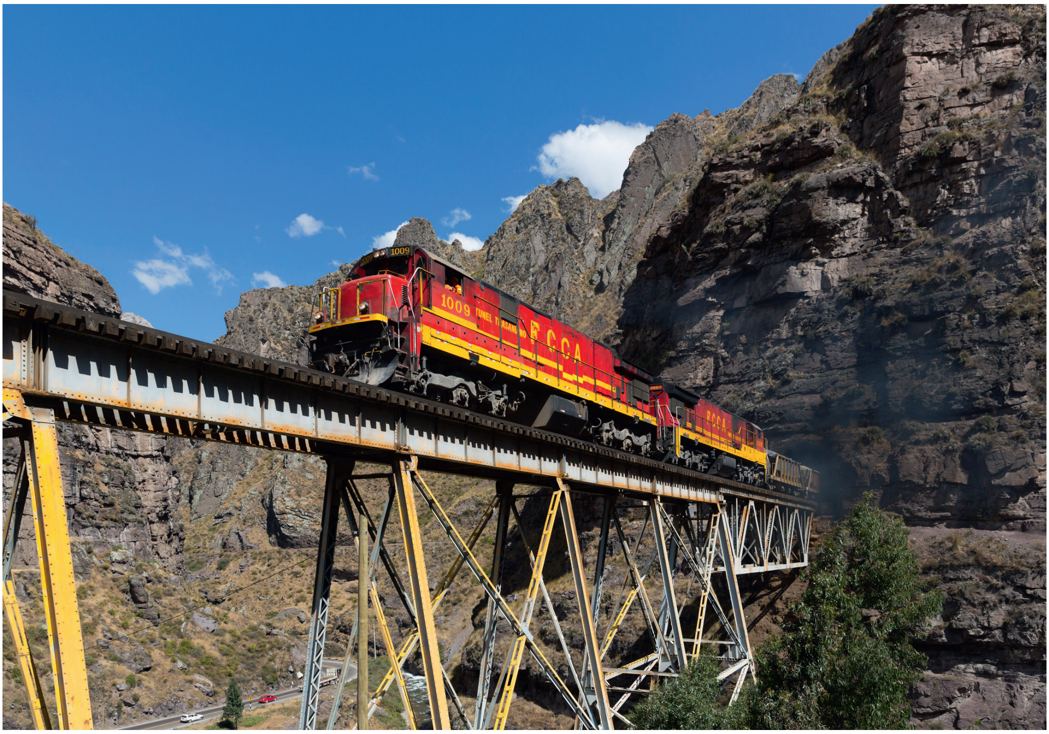
which are characterised by a high copper content (with the exception of chalcopyrite – 35 %).

One of the reasons for such an abundance of copper deposits in Peru and Chile is the very «young» age of the Andes, where there are still active volcanoes, including Llullaillaco, located on the border of Chile and Argentina, one of the highest volcanoes on Earth (6739 masl). There are frequent earthquakes, which indicates that the process of mountain formation is still far from complete. And volcanic processes, as you know, promote movement of rocks from lower layers of the earth's crust to the upper ones. Copper is an element with a higher density than, for example, silicon or aluminum. Accordingly, the oxides of these elements are found in the lower layers of the earth's crust.

The share of metals – in the form of ore or in pure form – in Peru's export remains large and fluctuates within 50 % (Table 4). Copper ore is mined:

- in deep mines due to construction of deep vertical shafts and chiselling of horizontal drifts;
- in open-pit mines, for deposits at shallow depths, where ore is mined after removal of layers of barren rocks; at present, about 90 % of copper ore is mined in open-pit mines.

Ore is transported by large trucks (mining dump trucks), often without a driver, using a GPS navigation satellite system. Copper ore




***Locomotive series GE C30–7 № 1008 + 1009 on a steel bridge between Rio Blanco (134th km, 3506 m above sea level) and San Mateo (14.07.2013). Photo: Kabelleger / D. Gubler.***

Table 7

**Copper ore processing**

| Stage | Process | Process description | Chemical reaction | Remarks |
|---|---|---|---|---|
| 1 | Crushing and grinding | Crushing of ore into powder in large cylindrical ball mills | – | The content of copper in the powder is ~2 % |
| 2 | Froth flotation | Mixing ore with paraffin oil to obtain a hydrophobic mineral surface and water bath with a foaming agent. By pumping in air, the foam collects mineral particles on the surface of water, while barren residues fall on the bottom of the tank | – | Copper content in the resulting mass is ~25 % |
| 3 | Roasting | Roasting of ore concentrate recovered in froth flotation process, i.e. conversion of beneficiated copper ore into a mixture of copper sulphides at temperature 500–700°C | $2\ CuFeS_2 + 3\ O_2 \rightarrow 2\ FeO + 2\ CuS + 2\ SO_2$ | Toxic $SO_2$ can be used for production of $H_2SO_4$ |
| 4 | Melting with introduction of fluxes | Calcinate is heated to a temperature > 1200°C with fluxes, for example, $SiO_2$, or $CaCO_3$, as a result, slag is formed, which is easy to remove and copper matte, i.e. iron sulfide and copper sulfide | $FeO + SiO_2 \rightarrow FeO{\cdot}SiO_2$ (slag) $Cu_2S + O_2 \rightarrow 2\ Cu + SO_2$ | |
| 5 | Converting converter matte into converter copper | Oxidation of copper matte in a shaft furnace | $2\ FeS + 3\ O_2 + 2\ SiO_2 \rightarrow 2\ FeO{\cdot}SiO_2 + 2\ SO_2$ $Cu_2S + O_2 \rightarrow 2\ Cu + SO_2$ | A blister is used to obtain copper |
| 6 | Casting of copper | The casting process is carried out in a carousel car. The surface of the anode is about 1 $m^2$ | – | The purity of the obtained copper is 99 % |
| 7 | Electrolytic refining | The process is carried out in an electrolytic purification tank in $CuSO_4 + H_2SO_4$ (200 A, 1,3 V) solution. And it consists in the electrolytic dissolution of the anode and the simultaneous deposition of cathode copper on the bottom of the tank; insoluble sludge contains Au, Ag, Pt and Sn (for use) | anod: $Cu \rightarrow Cu^{2+} + 2\ e^-$ katod: $Cu^{2+} + 2\ e^- \rightarrow Cu$ | The purity of the obtained copper is 99,99 % |

Source: compiled by the author of the article.

sometimes contains nuggets of silver and gold, which are mined both in Peru and Chile in significant quantities (Tables 5, 6).

The production of copper from ore is a multi-stage process (Table 7), which is accompanied by release of toxic sulfur oxide, which can be used, for example, for production of sulfuric acid. This process requires a lot of energy to create a high temperature (1200°C).

Despite the fact that copper is an element of vital importance to humans (the daily norm is 2–3 mg, maximum 10 mg), it becomes poisonous in large quantities (for example, the lethal dose of copper sulfate is only 30 g).

Silver and gold, which often «accompany» copper ore, are not toxic[6] to humans. But in the process of their extraction and purification, among others, mercury and solutions of potassium or sodium cyanide, which are very strong poisons, are used in significant volumes (a lethal dose is 50–100 mg of KCN or NaCN for an adult). For this reason, mining of these three metals requires strict adherence to occupational safety and health requirements.

The power industry in Peru is characterized by the widespread use of hydropower (26 %) and energy from natural gas (25 %) (Table 8). Ore processing plants use electricity generated by hydroelectric power plants, which seems like the easiest solution. Electricity is used primarily in the electrolytic refining of copper. The copper content in the ore, even after beneficiation, is only 2 % (Table 7), therefore it is more profitable to process ore at the places of its extraction than to transport it by train to

[6] Silver compounds are toxic to microorganisms.

**Table 8**

**Primary energy balance in South and Central America (2019)**

| | | Oil | Gas | Coal | Nuclear power plants | Water power plants | RES |
|---|---|---|---|---|---|---|---|
| Argentina | % | 34,3 | 49,4 | 0,7 | 2,2 | 9,5 | 4,0 |
| Brazil | | 38,1 | 10,4 | 5,3 | 1,2 | 28,7 | 16,3 |
| Chile | | 45,8 | 14,1 | 17,1 | – | 11,2 | 11,6 |
| Ecuador | | 66,8 | 3,1 | – | – | 29,7 | 1,0 |
| Columbia | | 36,5 | 25,2 | 13,4 | – | 23,9 | 1,1 |
| Peru | | 43,7 | 25,8 | 1,9 | – | 24,3 | 4,6 |
| Trinidad and Tobago | | 11,6 | 88,9 | – | – | – | 0,0 |
| Venezuela | | 31,7 | 42,7 | 0,1 | – | 25,3 | 0,1 |
| Others | | 62,2 | 7,7 | 5,5 | – | 17,8 | 6,7 |
| Total | | 41,4 | 20,8 | 5,2 | 0,8 | 22,3 | 9,5 |

Source: BP Statistical Review of World Energy, 2019.

*Ernest Malinowski*

factories located in valleys, for example, to Lima, where almost half of Peru's industrial production is concentrated. As mentioned above, density of copper is high, more than that of iron ores, so the cars should be loaded incompletely so as not to exceed the permissible axle load.

**Ernest Malinowski and Henry Meiggs – outstanding personalities**

Two persons, without whom Central Railway of Peru would not have been built, are Polish engineer Ernest Malinowski and American businessman Henry Meiggs. Their knowledge, courage, sometimes even audacity, ability to win over people made it possible to build this unique railway. The applied technical solutions, despite the difficult relief and climatic conditions, are still admired. Moreover, all construction work was carried out with ordinary shovels, pickaxes, and one-wheeled wheelbarrows, and the project itself was developed on a drawing board using a pencil, a drawing triangle and a mold.

**Ernest Malinowski** (1818–1899) was born into a wealthy noble family in Volhynia (his maternal grandfather was Podolsk voivode) [1; 7]. Malinowski family owned an estate in Rozhichnaya in Podol, which was confiscated by the tsarist government after November uprising. Ernest had two brothers and a sister – an older sister Leontina (died before 1831) and a brother Rudolf, as well as a younger brother Sigmund. In 1827–1831 young Ernest studied at Kshemenets Lyceum. After November uprising of 1831, in which brother Rudolph (joined the rebel army) and father Jakub (was the ambassador of the rebel diet) participated, brothers Ernest and Sigmund with their mother (Anna Malinowksaya) left for Galicia. After suppression of the uprising, Anna, together with her youngest son Sigmund, returned to Volhynia, while her father and two sons (Ernest and Rudolf) left for Dresden, and then for Paris. In France, Ernest continued his studies at the Lycée Louis-le-Grand in Paris, and then at the famous École Polytechnique and at the National School of Bridges and Roads (École nationale des ponts et chaussées). Having received an engineering degree, Malinowski began working on construction of Paris–Le Havre railway in 1838, and in 1839 he participated in construction of roads and a port in Algeria. He took part in works on the Meuse river near the border with Belgium, as well as in works to improve navigation conditions on the Cher river. Malinowski's South American period began in 1852, when he entered into a seven-year contract for «employment as a government engineer» in Peru, for [10]:

• development of projects for roads and bridges;

• supervision over implementation of construction and reclamation investments;

• drawing up topographic maps;

• training of local technical staff.

Malinowski went to Peru by ship, together with two French engineers – Emile Chevalier and Charles Fraguette. On the spot, he founded the first technical school – Escuela Central de Ingenieros Civiles and an organization uniting engineers – Comisión Central de Ingenieros Civiles. The first works in which Malinowski took part were the projects of paving streets and squares in Arequipa and modernisation of the stone bridge of Izacuchaca. The contract was extended by Malinowski for another three years in 1858. The first railways designed by Ernest Malinowski were [3]:

• Pisco–Ica (74 km) in 1859, together with Mario Alléon and Gerrit Backus;

• Chimbote–Huaraz (277 km; only 136 km were built due to financial constraints) in 1864, with Stephen Crosby and D. N. Paddison. The level difference on this road was > 3000 m. E. Malinowski also supervised the work.

During the War of Independence between Peru and Spain in 1866, Malinowski was appointed chief engineer at the port of Callao, where, together with Felippe Aranciba and José Cornelio Borda, he prepared a project for fortifying the port. He also participated in the defense of the port, fighting on the ramparts of Fort Santa Rosa. Malinowski used many innovative engineering solutions to protect the port. He used large-caliber cannons that remained after the American Civil War. They were armoured and placed on railway platforms so that the guns could easily change their position. This significantly increased the mobility of the artillery and gave the enemy the impression that the defense had more guns than it actually did. In recognition of the merits of Ernest Malinowski to the people of Peru, he received a diploma, medal and honorary citizenship.

***Henry Meiggs***

Engineer Malinowski's greatest endeavor in his life was participating in design and construction of the Peruvian Central Railway. In 1868, he began cooperation with Henry Meiggs, a businessman from the United States, who received an order to develop a feasibility study for a railway and entrusted this task to E. Malinowski. After recruiting the team and eight months of work, in April 1869 Malinowski handed over to H. Meiggs a detailed report. And already in December 1869, an agreement was signed (they say that bribes could not be avoided) between the company of H. Meiggs and the government of Peru on construction of Central Railway, which was to be built within six years for 27,6 million pesos (~ 22 mln US dollars). E. Malinowski, as chief engineer, was entrusted with the supervision of the construction of the line. It was precisely written that:

• the cost of construction of the railway will be financed by the Peruvian government, and the settlement with contractors will be made through the transfer of coupons with annual interest;

• payment of remuneration to engineers and workers is carried out by H. Meiggs from his funds;

• H. Meiggs' company will buy out land plots from private owners located on the route of the future railway;

• the government will donate state land plots.

Work began in January 1870, and at the first stage, during construction of a section of the road through the Rimac River valley, everything went smoothly. Difficulties began at the 54th km at an altitude of 860 masl at Chosica station, where the mountainous relief began. The hired workers were mainly Peruvian Indians, Chileans, Chinese coolies, Italian emigrants and African Americans, with a total of about ten thousand people. E. Malinowski personally supervised the work, kept the accounting department, established contacts directly with suppliers of rolling stock and construction materials, and also oversaw the provision of appropriate working conditions and timely payment of remuneration to hired people.

Sometimes he personally climbed steep mountain slopes in order to provide a technical solution to a particular issue, or descended a rope into an abyss in order to examine the strength of the soil in the places where the bridge piers were installed. He considered himself a part of the team – he worked, ate and slept together with employees, together with everyone he suffered from the difficult Peruvian climate – heat during the day and frost at night.

In 1874 the Government suspended funding for construction. Then H. Meiggs and E. Malinowski began to finance the railway from their own funds.

The innovative technical solution on this railway was the so-called zig zag, switchback, and reversed travel direction, i.e. double change of direction of travel, which allowed maintaining a maximum gradient of 40 ‰ for the railway line. It was an impressive success, after which Ernest Malinowski was recognised as an outstanding engineer, as it was published in technical magazines in Peru and around the world. The first section of Central Railway, 141 km long between Callao and Chicla, was opened for operation in May 1878. Malinowski, meanwhile, left for neighbouring Ecuador, where he participated in construction of Guayaquil-Quito railway line, including Chimbo and Sibambe sections located in the mountainous parts of the Western Cordilleras. In 1879–1881 in Peru there was a war with Chile, for this reason construction of the railway was suspended. Malinowski returned to Peru in 1886 to participate in construction of Tarma–La Merced railway line with other Polish emigrants V. Falkersky and K. Vakulsky. In 1890 Malinowski became a shareholder of the Peruvian Corporation, which was formed, among other things, with the aim of completing construction of the Central Andean Railway: in 1893, another (very important) section was built to La Oroya station.

Ernest Malinowski was not only an outstanding engineer, he was a very talented manager. Engineer Malinowski often visited the elite of Peruvian society, rich and influential people. He lived in an elegant hotel in Lima, ran an open house in which he received many guests, and hired a French chef. He was often invited to the houses of the upper strata of society. Malinowski was engaged in philanthropic activities. He was the author of two books: «Money of Peru», Lima, 1856 (La moneda en el Péru, Lima 1856) and «Central Andean Railway of Peru», Lima, 1869 (Ferrocaril Central-Transandino, Lima 1869), as well as for several articles for the institute's «Miners' Bulletin» (Boletin de Minas). Malinowski was a great connoisseur of classical and modern literature.

It should be noted that Ernest Malinowski always tried to help Polish emigrants. He hired engineers: A. Babinsky, V. Volkersky, E. Khabikhov, V. Klugerov, A. Mechnikovsky and K. Vakulsky. He helped biologists K. Yelsky and I. Semiradzsky.

Ernest Malinowski died in 1899 from a heart attack, was buried with honours as a national hero in the cemetery «Pastor Matias Maestro» (Presbitero Maestro) in Lima. In 1999, a monument to Ernest Malinowski was unveiled near Ticlio station. The author of the monument was the famous Polish sculptor Gustav Kazimierz Zemla (the author of the famous «Wings» installed in Katowice). The monument was made from granite in Poland. It is written in Spanish and Polish: *Ernest Malinowski, 1818–1899. Polish engineer, Peruvian patriot, hero of the defense of Callao in 1866, builder of Central Railway.*

**Henry Meiggs** (1811–1877) was born in Catskill, New York State in the USA, was the third of nine children of Elijah and Fenny Meiggs [9; 12]. His father ran the shipyard, in which young Henry also began to work. But having become independent, Henry decided to go into the lumber trade. He didn't succeed, went bankrupt twice. When information about the gold deposits in California («gold rush») emerged in the early 1850, Meiggs traveled across the country to San Francisco on a ship loaded with lumber. Then there was still no railway around, neither the Panama Canal[7]. Meiggs correctly calculated that lumber would

[7] Built in 1904–1914, officially opened in 1920.

be needed immediately and in large quantities to build a new city. His calculations were justified (the profit from sale of lumber was almost twenty times more than expenditures). With the money he earned, on North Beach waterfront, Meiggs built a warehouse, a sawmill, and a yard to bring in and process lumber and provide port services. The high demand for lumber continued as the city continued to develop, so Henry Meiggs' company was doing well. But Henry Meiggs also became famous as a prominent speaker and talented administrator, so he decided to become a city deputy. In 1853, Meiggs decided to build a pier 650 meters out to sea. The investment was a failure due to strong sea currents. In addition, the «gold rush» gradually began to fade, and the number of residents – to decrease. The real estate market plunged into another crisis. Henry Meiggs had collected loans by that time and paid them off with money from city funds. For this «criminal» reason, he very quickly packed up and left the United States with his family, taking all his property to the ship. After three months of travelling, Henry arrived in Chile and turned his energies into railway projects. He received his first order in 1857, and until 1867 built more than 300 km of railways. Along with entrepreneurial activities, he actively participated in public life and charity events. In 1868 he moved to Peru, where he built more than 1100 km of railways, including the Central Railway in cooperation with Ernest Malinowski. This allowed him to accumulate significant capital and pay off debts in his homeland, where he still planned to return someday. By 1873, Meiggs had paid off all debts with interest. But in the end he never returned to the United States and remained in Peru for the rest of his life.

**Conclusion.** The Central Andean Railway of Peru, built at the turn of 19th–20th centuries was a great project. Despite a very modest budget, in the absence of whatever technologies for building railways, it was nevertheless implemented. The project and construction of the railway was carried out mainly by foreigners, including the American businessman H. Meiggs and the Polish engineer E. Malinowski. Currently, half of Peru's exports are metals, including copper and gold, which are mined in the Andes, so the Central Andean Railway is still actively operated, generating significant profits for the state. Along with the enormous importance of the Central Andean Railway for the economy of Peru, travel along the entire route can be safely called a «journey for unforgettable impressions», which testifies to a person's desire to conquer and equip new territories, which would have been impossible without contribution of the railway.

## REFERENCES


1. Bartkowiak, D. Ernest Malinowski, konstruktor kolei transandyjskiej, Poznań, 1996.
2. Bernhardt, D., Reilly, J. F. II Mineral commodity summaries 2019. Reston, Virginia: U.S. Geological Survey, 28 February 2019.
3. Bielicki, Z. Wyżej niż kondory Poznaj Świat R. XXVIII, nr. 9 (334), Wrzesień, 1980.
4. Binns, D. The Central Railway of Peru and the Cerro de Pasco Railway. Skipton: Trackside Publications, 1996.
5. Camacho, S. Los Ferrocarriles del Perú, Colección de leyes, decretos, contratos y demás documentos relativos a los ferrocarriles, del Perú, hecha de orden de D. Enrique Meiggs. Tomo I, Lima, Imprenta del Estado, calle de la Rifa Nº 58, 1876.
6. Fawcett, B. Railways of the Andes (2nd ed.). East Harling: Plateway Press, 1997.
7. Inżynierowi Ernestowi Malinowskiemu w setną rocznicę śmierci *Zeszyty Naukowo-Techniczne Oddziału Stowarzyszenia Inżynierów i Techników Komunikacji w Krakowie,* t. 4, Kraków, 1999.
8. Marshall, J. The Guinness Railway Book. *Enfield: Guinness Books,* 1989.
9. Myers, E. P. South America's Yankee Genius, Henry Meiggs. *New York Messner*, 1969.
10. Raczko, D. Ernest Malinowski – koleją między chmurami. *National Geographic,* 12/1999.
11. Securities and Exchange Commission Washington, D.C. 20549 Form S-4 Registration Statement Under The Securities Act Of 1933 The Doe Run Resources Corporation. As Filed with the Securities and Exchange Commission on May 11, 1998. [Electronic resource]: https://www.sec.gov/Archives/edgar/data/1061112/0001047469–98–018990.txt.
12. Stewart, W., Henry Meiggs, Yankee Pizarro, Durham, N.C., *Duke University Press,* 1946.
13. The Atlas of Economic Complexity. Harvard Growth Lab's research and data visualization tool used to understand the economic dynamics and new growth opportunities for every country worldwide. [Electronic resource]: https://atlas.cid.harvard.edu/explore?country=173&product=undefined&year=2018&productClass=HS&target=Product&partner=undefined&startYear=1995. The World Copper Factbook 2010. International Copper Study Group.
14. Thomson I. The dieselization of the Central Railway of Peru. Diesels & Electrics, 1: 54–9, 2003.
15. United States Securities And Exchange Commission Washington, DC 20549 Form 10-Q/A (Amendment No. 1) Quarterly Report Pursuant To Section 13 OR 15(d) Of The Securities Exchange Act Of 1934 For the quarterly period ended April 30, 2006. [Electronic resource]: https://www.sec.gov/Archives/edgar/data/1061112/000101124006000058/doerun10qa2dqtr101906.html.
16. Whetham, R. D. Railways of Peru. Vol. 2. The Central and Southern Lines. Bristol: Trackside Publications, 2008.
17. Camacho, Simón. Los Ferrocarriles del Perú. Volume I, 1876. Government Printing Office, Calle de la Rifa N°. 58, Lima, pp. 115–116.